10.1071/PVv2010n148p41

A multi-disciplinary site investigation for the assessment of drilling geohazards and environmental impact within the northern Bonaparte Basin

Tony George[1,3] and Eric Cauquil[2]

[1]*FUGRO Survey Pty Ltd, Perth, WA, Australia.*
[2]*TOTAL E&P, Paris, France.*
[3]*Corresponding author. Email: t.george@fugro.com.au*

Introduction

TOTAL E&P Australia (TOTAL) is a leading multinational oil company which has only recently entered into the Australian energy exploration market. Two exploration wells named Durville and Laperouse are programmed for 2010 in the northern Bonaparte Basin, off the north-western cost of Western Australia in water depth of approximately 100 m (see Figure 1). In the frame of this exploration program, and in order to comply with TOTAL company rules and Australian regulation, TOTAL has contracted FUGRO Survey Pty Ltd (FUGRO) to provide geophysical and environmental baseline surveys. The first objective of this survey was to assess the seabed conditions and the shallow geology for the installation of a drilling rig. The second objective was to assess the environmental conditions of the drilling sites. The area is known to contain shoals and fossil reefs, and it was mandatory to map them in detail and to assess whether they are still actively growing, via a visual inspection.

Regional setting

The Bonaparte Basin is a predominantly offshore sedimentary basin which covers an area of approximately 270 000 square kilometres off the north-western coast of Western Australia (Kraus and Laws, 1974; Cadman and Temple, 2003). The basin contains an approximately 15 km thick sequence of Phanerozoic marine and fluvial sediments. The Bonaparte Basin adjoins the Browse Basin to the south, and the Arafura and Money Shoal Basins to the Northeast, along the Darwin Shelf. The northern margin of the basin is the Timor Trough, where water depths exceed 3000 m.

Numerous phases of sedimentation have occurred within the basin during various tectonic events and glacial/interglacial sea level cycles. The most recent sedimentary environment of the Late Cretaceous and Cainozoic typically comprised prograding sequences of shelf carbonates, forming thick sequences of sandstones, mudstone and limestones.

Previous studies have found the seabed in this part of the Timor Sea to comprise numerous carbonate reefs and/or shoals which have developed periodically over a number of glacial and interglacial sea level changes. The reefs are likely to consist of both hard coral growth and carbonate sediment deposits. During the last sea level regression the sea-surface was 100 to 140 m below the present level, resulting in both the sub-aerial erosion and compaction of these reefs. This was followed by a reef-building episode as sea level began rising again approximately 18 000 years before present (b.p) (Camoin et al., 2004). Sea level then rose rapidly between 15 000 and 13 000 years b.p., inundating the reefs. Corals grow through a symbiotic relationship with photosynthetic algae, and thus do not grow at depths below the lower limit of the photic zone, approximately 50 m below the sea surface. The current water depth in the survey area is approximately 100 m, which suggests that reefs would not be actively growing (Kleypas and Gattuso, 2010).

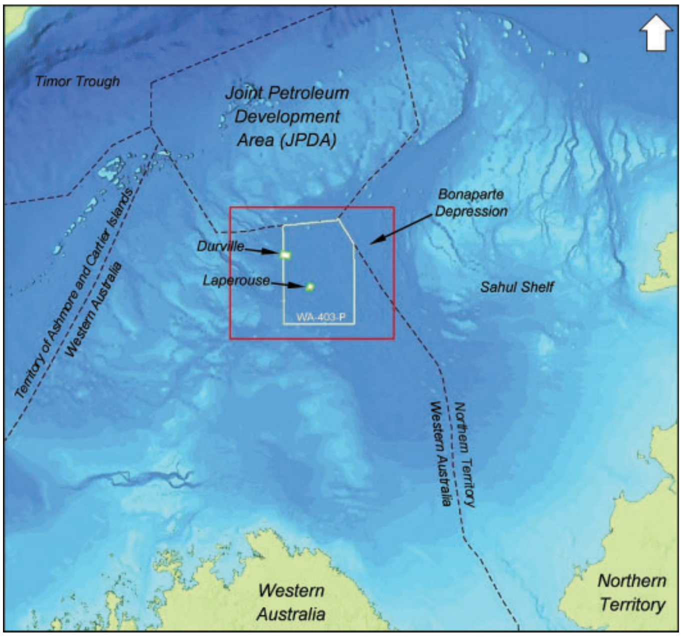

Fig. 1. *General location diagram showing the location of the study areas.*

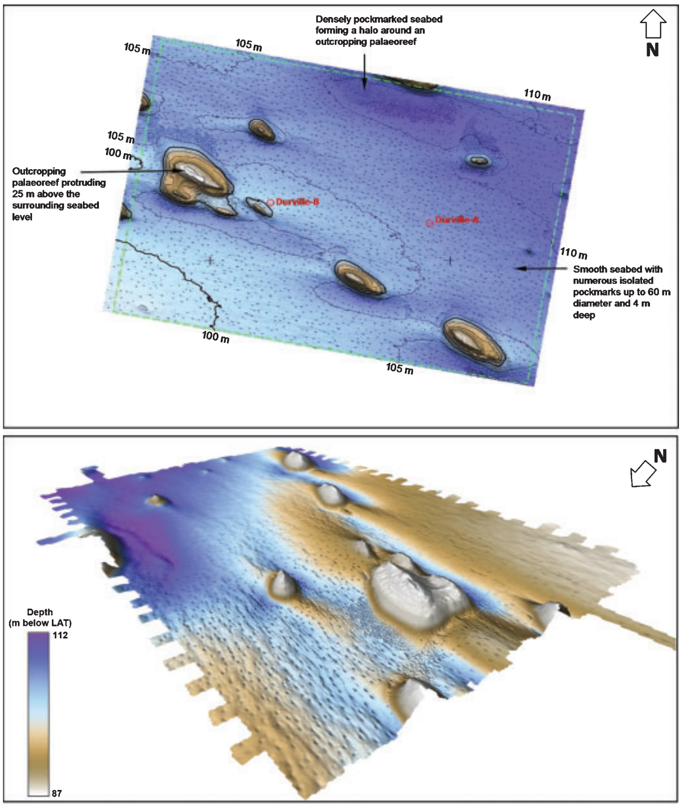

Fig. 2. *Shaded relief bathymetric digital terrain model and 3D perspective view of the Durville site.*

The Bonaparte Basin is a proven petroleum hosting province, with over 70 identified petroleum accumulations. The basin contains the necessary prerequisites for further discoveries, with mature source rocks, good quality reservoirs, and traps over wide areas of the basin. Numerous papers are available summarising the petroleum potential of the basin (Colwell and Kennard, 1996; McConachie et al., 1996; Kennard et al., 2003).

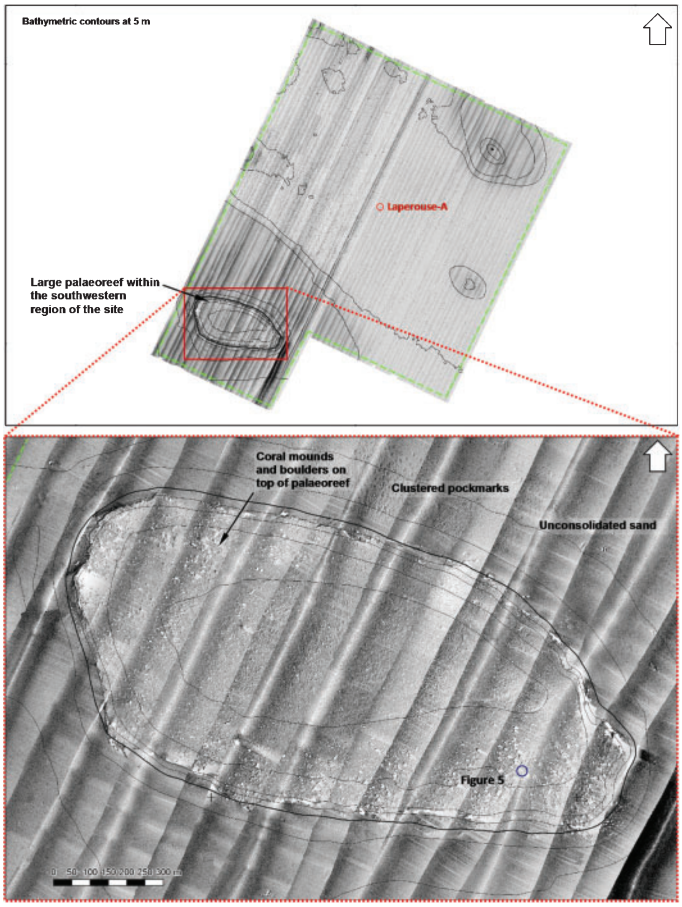

Fig. 3. *Side scan sonar mosaic of a palaeoreef in the southwest Laperouse site.*

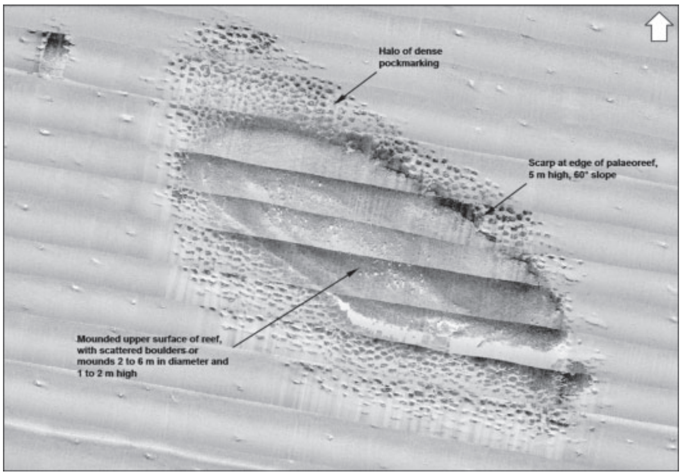

Fig. 4. *Densely pockmarked seabed surrounding a palaeoreef in the Durville survey area.*

Survey operations

The survey work was conducted between October and November 2009. The survey equipment involved conventional geophysical sensors including a high resolution multibeam echo sounder, a dual-frequency (120/410 kHz) digital side scan sonar, chirp and boomer sub-bottom profilers and assorted peripheral systems. Based on the findings of the geophysical survey an environmental baseline study was conducted which involved a soil and water sampling program as well as several video transects. The use of these high resolution systems aboard FUGRO's dedicated offshore geophysical survey vessel, the *M.V. Southern Supporter*, combined with a calm weather period during the survey, allowed very high quality data to be acquired.

Survey findings

The present day seabed conditions are clearly revealed by multibeam and side scan sonar data. A digital terrain model from the Durville site, and a side scan sonar mosaic from the Laperouse site are shown as Figures 2 and 3 respectively. The seabed at both sites is generally flat, with numerous pockmarks and a number of outcropping palaeoreefs, the largest of which protrudes 35 m above the surrounding seabed.

Pockmarks form as a result of fluid or gas escape from marine sediments. Isolated pockmarks across the two sites typically have diameters of up to 20 m, and are generally up to 2.5 m deep. Around the flanks of the outcropping palaeoreefs, the pockmark density increases dramatically (Figure 4). These pockmark halos around the palaeoreefs may indicate that the reefs are acting as channels for the release of shallow fluid and gas escape, or may be the result of thinner sediment cover over buried cemented material resulting in a faster rate of fluid/gas release in the overlying sediments. Previous studies have noted gas seepage from pockmarks within the Timor Sea (O'Brien et al., 2002); however, no evidence of such activity was seen during this survey.

The palaeoreefs within the Durville site range between 80 m and 1500 m in length, and are elongate with WNW/ESE orientation.

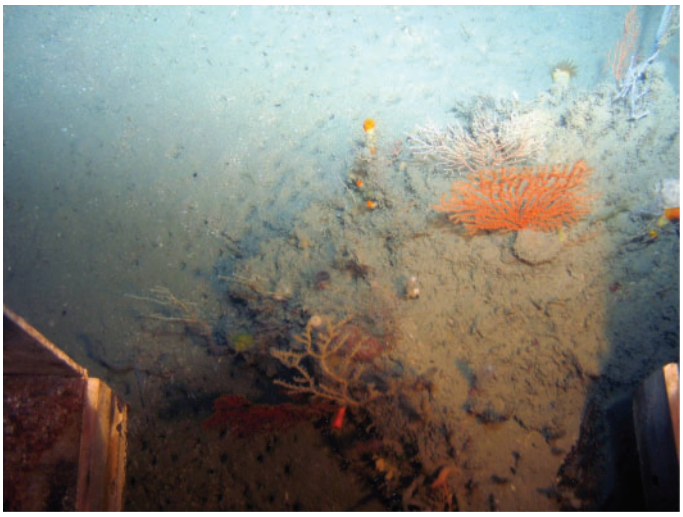

Fig. 5. *Photo of a coral boulder on top of the palaeoreef in the southwest Laperouse site. The boulder has several live gorgonian corals, however the palaeoreef is covered in a layer of sandy silt and clay, and is not actively growing.*

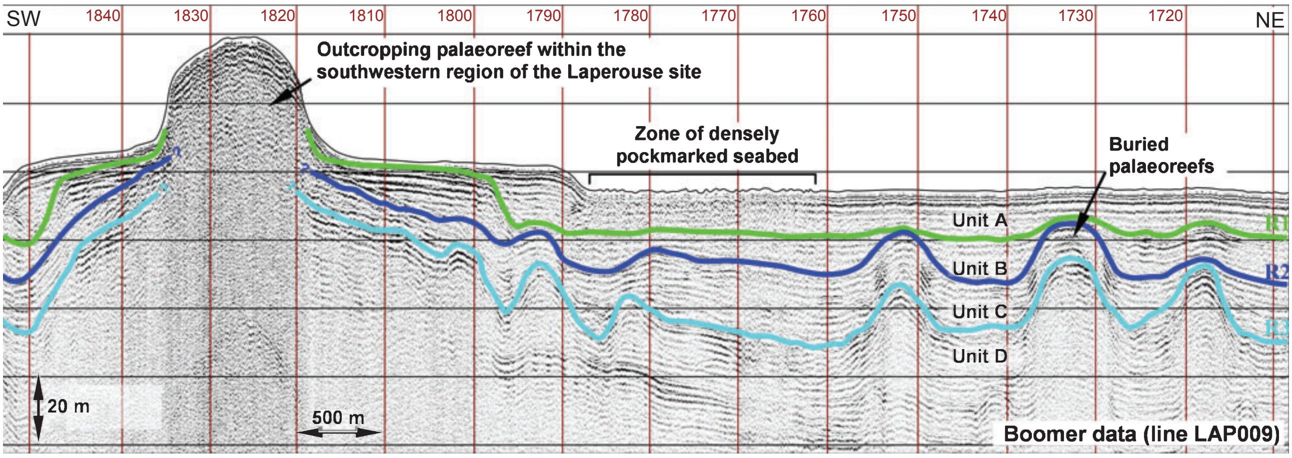

Fig. 6. *Boomer sub-bottom profiler data on survey line LAP009 showing interpreted major reflectors indicating changes in reef building episodes and depositional environment.*

The top of the largest reef is approximately 35 m above the surrounding seabed level.

The reefs are less numerous in the Laperouse site, with only two outcropping palaeoreefs. However, a high number of palaeoreef outcrops (>100) are observed within the permit area. The outcropping reef in the northeast of the site is approximately 500 m long and 200 m wide, and a large reef 1500 m long and 800 m wide is located in the southwest corner of the site. Several other low seabed mounds are observed within the site, which may indicate buried palaeoreefs below a layer of unconsolidated sediments.

The morphology of the reefs in both sites is similar, with steep reef edges up to 60°, and broad, low gradient reef tops with scattered boulders and mounds up to 2 m high.

A number of seabed photographs taken over the top of the large palaeoreef in the southwestern Laperouse site show that the palaeoreefs are covered with a layer of unconsolidated, i.e. recent, sandy clay and silt (Figure 5; location shown in Figure 3). The rugged, coralline nature of the palaeoreef remains evident but the hard, reef-building corals appear to have ceased activity, leaving gorgonians as the primary sessile organism.

In addition to the outcropping palaeoreefs at the seabed, there are a number of smaller, fully buried palaeoreefs which were identified in the boomer sub-bottom profiler data. Seismic

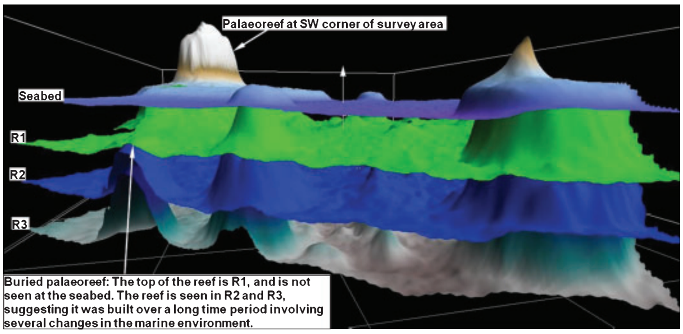

Fig. 7. *3D model showing below LAT to reflectors R1, R2 and R3. View is from NE to SW. Vertical exaggeration is 30 : 1.*

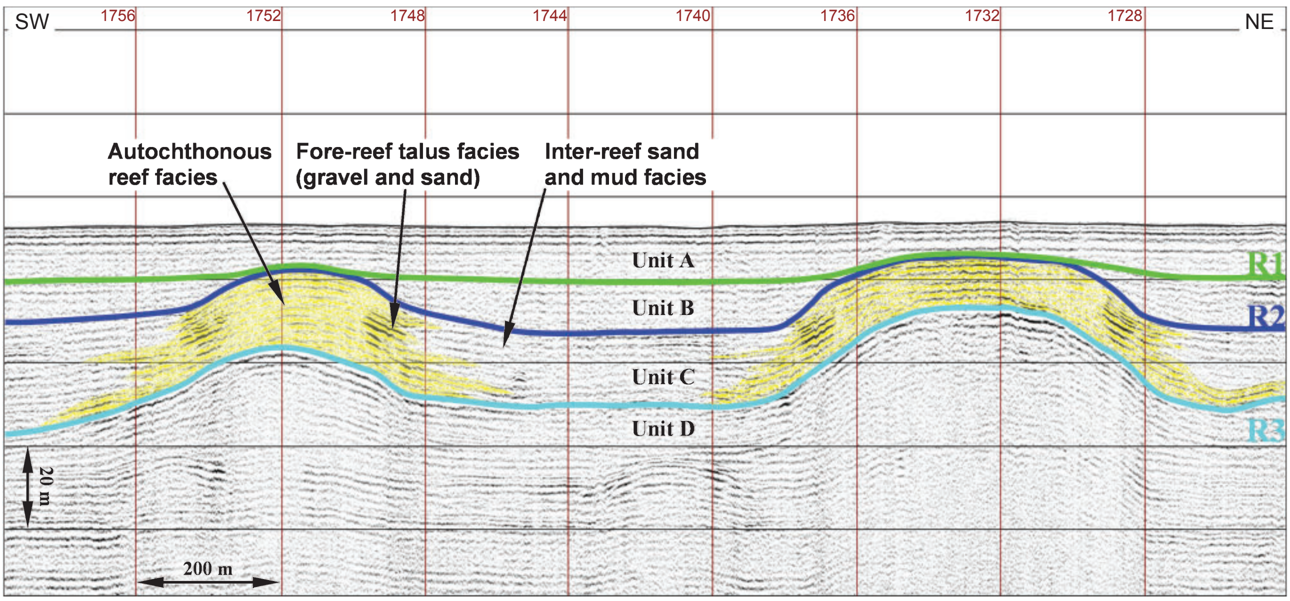

Fig. 8. *Boomer sub-bottom profiler data example showing facies change at the flanks of palaeoreefs.*

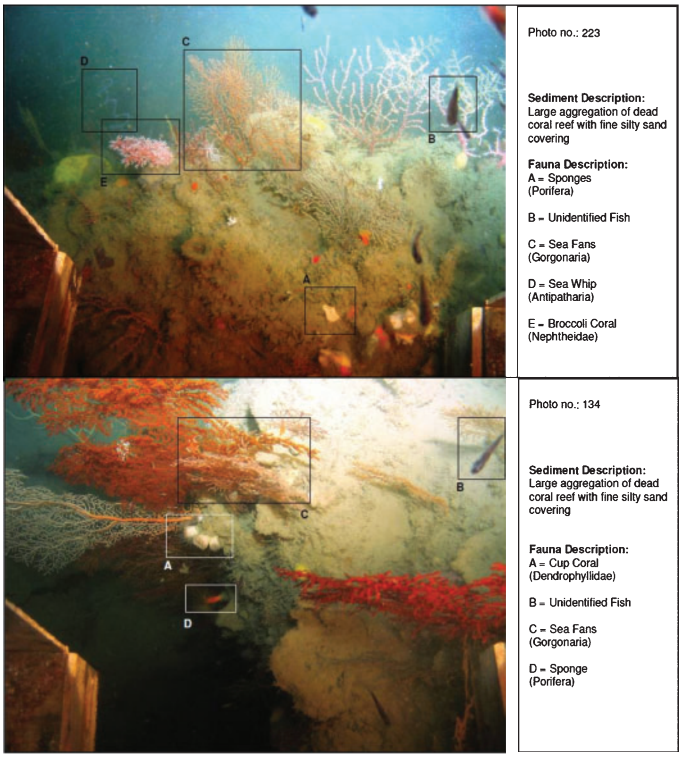

Fig. 9. *Drop camera photos from the Laperouse site showing typical marine organism assemblages.*

penetration through the cemented palaeoreefs is often poor. However the data shows that the palaeoreefs have built up over successive sea level cycles (Figure 6). Several acoustic reflectors are identified which are interpreted as marking the top of reef building/sedimentary episodes. The interpreted reflectors are likely to represent depositional hiati or erosional surfaces formed during previous sea level lowstands. Reflector R1 may be representative of the seabed and/or land surface as it was 18 000 years before present, while reflector R2 or R3 may represent the sea level lowstand of 150 000 years before present.

The depth to the tops of Reflectors R1, R2 and R3 (m below LAT) was mapped to determine the location and extent of the buried reefs within the Laperouse site (Figure 7).

In several seismic profiles, there is evidence to suggest that the edges of the buried reefs show interleaving and grading down from coral to gravel/sand fore-reef talus type facies, and finally down to inter-reef sands and muds (Figure 8). This evidence would support the interpretation that the reef grew periodically with changes in the marine environment.

Environmental baseline survey

To complement the geophysical data, TOTAL commissioned an environmental baseline study. The study comprised physical samples from ten locations within each site, as well as water sampling and profiling and underwater photography. From each sample site, three samples were retained for macrofaunal analysis, and one sample for physio-chemical analysis.

Throughout the survey areas, readings were generally consistent with unpolluted seawater baseline standards for contaminants, such as heavy metals and hydrocarbons. The exception to this was elevated zinc levels recorded across both sites. Zinc levels in seawater are typically less than $0.1\,\mu g\,L^{-1}$; however, across the two survey areas, zinc levels of 15 to $29\,\mu g\,L^{-1}$ were recorded suggesting a regional influence, although the origin of the elevated zinc level is unknown. Measured water column conductivity, temperature and salinity were consistent with regional data from CSIRO.

A towed drop-camera was used to record a series of images to aid interpretation of seabed morphological features and gain an understanding of the biodiversity within the sites. The images support the conclusions that the reefs are no longer actively growing. Figure 9 shows several images from the camera transects of the Laperouse site, showing the diversity of marine life, which is predominantly concentrated on top of the palaeoreef. Little abundance or diversity of life is observed elsewhere.

Conclusion

The findings of this survey corroborate the findings of other studies about the Bonaparte Basin, supporting the hypothesis that a barrier reef complex extended from the Sahul platform through to the Ashmore reef area approximately 18 000 years ago, during the last sea level regression. These reefs appear to have grown periodically with changes in the marine environment. When sea levels began to rise rapidly approximately 15 000 to 13 000 years b.p., the majority of the reef-building corals became extinct and were buried beneath successive layers of unconsolidated marine sediment. The present survey highlights the magnitude of the challenges that may encounter during a drilling campaign.

Conducting safe offshore operation whilst reducing the environmental impact of its activities is a key priority for TOTAL. The geophysical and environmental baseline survey conducted by FUGRO allows TOTAL to plan the forthcoming drilling campaign in a safe and environmentally friendly manner.

References

Cadman, S. J., and Temple, P. R., 2003, Bonaparte Basin, NT, WA, AC & JPDA: *Australian Petroleum Accumulations Report 5*, 2nd Edition, Geoscience Australia, Canberra.

Camoin, G. F., Montaggioni, L. F., and Braithwaite, C. J. R., 2004, Late glacial to post glacial sea levels in the Western Indian Ocean: *Marine Geology* **206**, 119–146. doi:10.1016/j.margeo.2004.02.003

Colwell, J. B., and Kennard, J. M. (Compilers), 1996, Petrel sub-basin study 1995–1996: Summary report: *Australian Geological Survey Organisation*, record 1996/40.

Kennard, J. M., Deighton, I., Ryan, D., Edwards, D. S., and Boreham, C. J., 2003, Subsidence and thermal history modeling: New insights into hydrocarbon expulsion from multiple petroleum systems in the Browse Basin: *Timor Sea Petroleum Geoscience, Bonaparte Basin and Surrounds*, Darwin, Northern Territory, 19–20 June 2003, Abstracts, 5.

Kleypas, J., and Gattuso, J.-P., 2010, Coral reef: in Cleveland, C. J. (Ed.), *Encyclopedia of Earth*.

Kraus, G. P., and Laws, R. A., 1974, Regional geology of Bonaparte Gulf-Timor Sea Area: *APPEA Journal* **14**(1), 77–84.

McConachie, B. A., Bradshaw, M. T., and Bradshaw, J., 1996, Petroleum systems of the Petrel Sub-basin – an integrated approach to basin analysis and identification of hydrocarbon exploration opportunities: *APPEA Journal* **36**(1), 248–268.

O'Brien, G. W., Glenn, K., Lawrence, G., Williams, A. K., Webster, M., Burns, S., and Cowley, R., 2002, Influence of hydrocarbon migration and seepage on benthic communities in the Timor Sea, Australia: *APPEA Journal* **42**(1), 225–239.